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Title: LS TRACKER SYSTEM

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PRIOR APPPLICATION

This application claims the benefit of U.S. Provisional Application Serial No. 60/239,260, filed October 12, 2000 entitled "LS TRACKER SYSTEM".

FIELD OF THE INVENTION

The present invention relates to an image tracking system used within broadcasting. More particularly, it relates to an apparatus which enables the tracking of images of moving objects or targets, and to a method of tracking such images.

BACKGROUND OF THE INVENTION

Filming and monitoring various images, events and scenes has lead to a great many advances and inventive leaps in image processing, camera technology and automation in capturing images of moving objects or events of interest. Increased microprocessor speeds have played a major role in advancing the quality and capabilities of film and image processing used in the broadcast industry.

Broadcast events usually require coverage of events incorporating moving objects within sporting events, wildlife documentaries or surveillance. As a result of this, various image tracking and processing systems have been developed in order to capture and track the movement of images relating to these moving objects. Furthermore electronic devices have been developed for inserting images into live video signals or broadcast image frames, such as those described in United States Patent No. 5,264,933.

United States Patent No. 6,100,925 describes a Live Video Insertion System (LVIS) that allows the insertion of static or dynamic images into a live video broadcast on a real time basis. The LVIS uses a combination of pattern recognition techniques and camera sensor data (e.g.

pan, tilt, zoom, etc.) to locate, verify and track target data.

United States Patent No. 5,706,362 describes an image tracking apparatus which selects the image of the target vehicle to be tracked, and stores this image in a reference image memory. The reference image and subsequent images are subjected to comparisons in order to determine changes between them as a result of the target vehicle position changing within each of the stored images.

Accordingly, there is a need for an image tracking method and apparatus capable of tracking the image of a moving object within broadcast image frames without the computation overhead required for processing and scanning image frames in order to determine the object or targets position in each frame. Furthermore, the provision of smooth tracking of a target image within broadcast frames provides a natural viewing perception of graphic images inserted into the broadcast frames for tracking the target (e.g. information balloons).

SUMMARY OF THE INVENTION

The present invention relates to an image tracking apparatus for tracking the movement of an image of a corresponding moving object. In one aspect the apparatus comprises: an optical identifier device which attaches to the moving object and generates an optical identification signal; and an image capture system for receiving the image of the moving object and the optical identification signal, and generating a coordinate position value related to the image of the moving object.

In accordance with another aspect of the present invention, a method of tracking the movement of an image of a corresponding moving object is determined by: generating an optical identification signal at the moving object, as the moving object moves; and receiving an image of the moving object and the optical identification signal, and generating a coordinate position value related to the image of the moving object.

DETAILED DESCRIPTION OF THE DRAWINGS

For a better understanding of the present invention and to show how it may be carried into effect, reference will now be made to the following drawings which show the preferred embodiment of the present invention, in which:

Figure 1 illustrates a system level diagram of an image tracking apparatus of the invention in use;

Figure 2 illustrates a functional display produced by the image tracking apparatus shown in Figure 1;

Figure 3 illustrates a block diagram of an object identifier device incorporated within the image tracking apparatus of Figure 1;

Figure 4 illustrates a block diagram of an image capture system comprising a two lens imaging system, which is incorporated within the image tracking apparatus of Figure 1;

Figure 5 illustrates an block diagram of an image capture system comprising a single lens imaging system, which is incorporated within the image tracking apparatus of Figure 1; and

Figure 6 illustrates the optical system within the single lens imaging system of Figure 5.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Figure 1 illustrates the operating principle of an image tracking apparatus. The image tracking apparatus comprises an optical identifier device **12** and an image capture system **14**. The optical identifier device **12** is attached to a moving object **16** such as a racing car, so that the optical identifier emits an optical identification signal over a 180° radius, as indicated at **18**. The wide optical emission area, indicated at **18**, ensures that the optical identification signal is received with the image of the moving object by the camera system, particularly when the camera system pans and zoom to follow the moving object **16** as it passes. The 180° emission area, indicated at **18**, of the optical identification signal is generated by a group of laser devices, wherein each laser device generates an optical

output, as indicated at **20**, representing a portion of the total optical emission area, as indicated at **18**.

The image capture system **14** includes a camera system and a picture frame processing system for receiving and processing the image of the moving object and the optical identification signal. The camera system **14** sees the optical identification signal as a point source of bright light, and depending on the angle of the moving object **16** with respect to the camera system **14** (during panning), at least one of the plurality of laser devices generates an optical output which is detected as a point source of light by the camera system **14**.

The camera system **14** generates a series of image frames corresponding to the image of the moving object **16** and the optical identification signal, and the picture frame processing system provides a succession of image processing steps on these frames. Following the image processing, the picture frame processing system generates a coordinate position value for the point source of light generated by optical identification signal emitted from the optical identifier device **12**. Consequently, the coordinate position value corresponds to a point on the image of the moving object **16** where the optical identifier device **12** is attached. The coordinate position value and image frames corresponding to the image of the moving object **16** are sent via a communication medium (e.g. coaxial cable, infrared, rf, etc.) or a communications link (e.g. satellite link), as indicated by **22**, to a TV broadcast network or broadcast cable company, as indicated at **24** for image display coverage.

Figure 2 illustrates the image display coverage for the moving object **16**. The broadcast image of the moving object **16** is received from the communication medium or link, indicated by **22**, as an NTSC composite image comprising an information graphic image **28**. The picture frame processing system superimposes the information graphic image **28** on the image frames corresponding to the image of the moving object **16**, whereby the thumb nail graphic **28** is inserted at the coordinate position value, as defined by **30**. As indicated above, this coordinate position value, defined by

30, is in close proximity to the optical identifier device **12** due to the emission of the optical identification signal from the optical identifier device **12**, which is processed by the image capture system **14** (Figure 1) . Within each NTSC frame period (~16ms), the picture frame processing system determines an updated value of the coordinate position value, indicated at **30**, based on the new location of the object image **16** within each of the series of image frames **32**. Therefore, as the image of the object moves within the image frames so does the graphic image **28**, such that the graphic image **28** follows the image of the object **16**.

The information inserted within the graphic image **28** is determined by a coding scheme incorporated within the picture frame processing system and optical identifier device **12**. Therefore, each moving object having an attached optical identifier device **12** is identified by a unique identifier code, which is modulated onto the optical identification signal by its corresponding optical identifier device **12**. In the example shown in Figure 2, the information inserted into the graphic image **28** refers to statistics and information relating to the driver of the car (moving object image **16**). The picture processor system decodes the received optical identification signal and determines what information to insert into the graphic image **28** based on the unique code extracted by the decoder.

Figure 3 illustrates a block diagram of the optical identifier device **12** comprising a plurality of laser devices **36** and a laser controller **38** for generating an electrical drive signal, indicated by **40**, for modulating the plurality of laser devices **36** with the unique identification code. The laser controller **38** includes a synchronization device **42** which includes a stable synchronized system clock **44** and a frame sequencer **46**. The laser controller **38** also includes a modulation controller **48** for receiving a timing enable signal, indicated at **50**, from the frame sequencer **46** and modulating the plurality of laser devices **36** with the unique identifier code.

The system clock **44** is synchronized to operate in phase with an existing system clock operating within the image capture system **14** (see Figure 1). As the image tracking apparatus can track several moving

objects (for example four moving objects) within a given NTSC frame period (~16ms), each moving object having an optical identifier device **12** must have its system clock **44** synchronized with all other system clocks. The synchronization can be achieved by activating each system clock **44** located at each remote object and activating the system clock **44** within the picture processing system simultaneously. The activation or resetting of these clocks can be done wirelessly using rf transmission or infrared transmission. Once the clocks have been activated simultaneously, they operate in phase with one another and stay in phase as a result of the inherent clock stability.

The frame sequencer **46** receives the clock output from the system clock **44** and generates the timing enable signal, indicated at **50**, at the start of each ~4ms subframe (four subframes in total) within each ~16ms NTSC frame. This causes the modulation controller device **48** to optically modulate the plurality of laser devices **36** with the unique code at the start of a ~4ms subframe period for a ~4ms duration. It will be appreciated that each subframe is a fraction of the NTSC frame period. Consequently, this allows several optical identifier devices to operate within its designated subframe within each NTSC frame.

A car identification code encoder **52** generates the unique identifier code either locally within the optical identifier device **12**, or it receives the unique identification code remotely using, for example wireless transmission (e.g. rf or infra red). The unique identification code received through wireless transmission is received by a coding controller **54**. The coding controller **54** sends the unique identifier code to the code encoder **52**, wherein the code encoder **52** drives the modulation controller **48** with the unique identifier code. The coding controller **54** may also receive a modulation delay value wirelessly, or it may generate the delay value locally within the optical identifier device **12**. The modulation delay value is received by a variable delay generator **56**, which generates a modulation delay signal, as defined by **58**. The modulation delay signal activates the modulation controller **48** (active for ~4ms) once every ~16ms between each

NTSC frame. The modulation controller **48** will be activated for ~4ms during the same subframe period within each NTSC frame and turned off for a ~12ms delay by the variable delay generator **56** between NTSC frames.

The modulation controller device **48** modulates the lasers **36** with the unique identification code when it receives the timing enable signal, defined by **50**, from the frame sequencer **46** and the modulation delay signal, defined by **58**, from the variable delay generator **56**. Consequently, the laser devices **36** go through a repeated cycle, where they are modulated (active) for ~4ms during each NTSC frame and turn off (disabled) for ~12ms between each NTSC frame. By dividing the NTSC frame into four subframes, four moving objects can be tracked using the optical identifier device **12**. It will be appreciated that by increasing frame processing speeds in broadcast camera technology, the number of allocated subframes and potential tracked moving objects will increase.

If four objects are being tracked for example, each moving object (e.g. race car) will have an object identifier device **12** which is activated (lasers modulated) within one subframe (a different one of four for each object). During the tracking setup, the delay generator **56** in each optical identifier device **12** is assigned a different modulation delay value in order to ensure that each optical identifier device **12** generates the optical identification signal within its own designated ~4ms subframe, or in other words is assigned an allocated subframe. Each optical identification signal corresponding to each of the four moving objects can now be processed by the image capture system within each NTSC frame. Once the variable delay generator **56** has provided the subframe allocation for each object, as mentioned above, the modulation controller **48** will be activated for ~4ms during each designated object's subframe period within each NTSC frame, and will be turned off for a ~12ms delay by the variable delay generator **56** between NTSC frames.

Within each optical identifier device **12**, approximately twenty laser devices **36** are arranged in order to generate an optical beam emission with an area of coverage of 180° degrees horizontal by 45°

vertical. Therefore, the modulated laser devices **36** generate the optical identification signal for a designated ~4ms subframe period within each NTSC frame, wherein the optical emission coverage area of the optical identification signal is 180° degrees horizontal by 45° vertical. As explained in the following paragraphs, the image capture system detects and processes the optical identification signal emitted from each optical identifier device **12** in order to constantly (within each NTSC frame) generate the coordinate position value of a point related to the image of the object. The position location of this point relative to the image of the object is determined by the activated optical identifier device **12** attached to the object. As previously explained, the image capture system sees the optical identification signal emitted from each optical identifier device **12** as a point source of bright light. It is this point source of light that is processed by the image capture system.

Figure 4 illustrates a block diagram of the image capture system **14** which includes a first camera **62**, a second camera **64** and a picture frame processing system **68**, wherein the picture frame processing system **68** is responsible for the acquisition and processing of image frames received from the first and second camera **62**, **64**. The first camera **62** is a broadcast camera used for generating a first series of image frames comprising broadcast quality NTSC image frames of filmed objects (e.g. race cars). The first camera **62** has a first lens **70**, which can be a Canon J55.

The second camera **64** is a high frame rate camera (four times NTSC rate) used for generating a second series of image frames which include image frames of the received optical identification signal emitted from each optical identifier device **12** attached to each filmed object. The image frames of the received optical identification signals emitted from each object are received by the picture frame processing system **68** in order to generate a coordinate position value for each point source of light produced on the image frames. Each point source of light on an image frame, identifies the position of the object within that image frame.

The second high frame rate camera device **64** has a second lens **72** which includes a narrow band optical filter **74**. The narrow band optical filter **74** receives images of the objects and the optical identification signals emitted from these objects, and generates optically filtered image frames. The filter only passes the wavelengths corresponding to the emitted optical identification signals. Therefore, the optically filtered image frames include only the point sources of light emitted from the objects being filmed by the first and second cameras **62**, **64**.

The mechanical structure or arrangement of the first and second cameras **62**, **64**, is such that they are placed side by side to form a single camera system for filming the same event. The difference between the two cameras is that one camera (first camera **62**) generates the broadcast quality images of the objects, whilst the other camera (second camera **64**) determines the position of the mentioned objects within each of the broadcast quality images.

The picture frame processing system **68** comprises a stable synchronized system clock **76**, a frame grabber **78**, a frame processor **80** and a unique identifier decoder device **82**. The optically filtered image frames corresponding to the optical identification signals are accessed by the frame grabber **78** and presented to the frame processor **80** for eliminating background noise from the optically filtered image frames. There is a probability that solar reflection off other objects may create bright spots within the optically filtered images and that they will be mistakenly processed as an optical identification signal from one of the moving objects being filmed. This is overcome by the frame processor **80** subtracting from each subframe accessed by the frame grabber **78**, the preceding adjacent subframe. The difference frame generated as a result of this subtraction is processed by determining which pixels within the difference frame have a saturation value below two hundred (saturation value at each pixel ranges between 0-255) and discarding them by applying a saturation value of 0 to them. Each point source of light received from the laser devices (Figure 3, reference character **36**) will produce a high saturation value at each camera

pixel (above 200) within each difference frame as a result of the point source moving relative to each NTSC frame. Solar reflections in the same pixel locations will cancel each other during the subtraction process. Another processing technique for discarding unwanted reflections is to observe the number of pixels illuminated by a reflection. If the bright spots are to large, they are attributed to reflections. It will be appreciated that many parallel processing steps are incorporated into the image processing stages within the image capture system. These processes are carried out over eight ~4ms subframes (2 NTSC frames) and are carried out in order to acquire the bright spots corresponding to the objects or targets being filmed. Once the objects have been acquired, each object's bright spot within the optically filtered image frames is processed in order to determine its coordinate position value.

In the case where the object is a moving car, at a distance of approximately 1200 feet, the image of the car moves across the pixel array of 512 pixels which generate the image frames in approximately one second. If four cars are being tracked, where each car emits an optical identification signal from an attached optical identifier device **12**, then each optical identification signal is emitted from each car every four subframes or ~16ms. This corresponds to the car moving approximately 8 pixels from its last position in the previous NTSC frame (or 4 subframes before). Therefore, the coordinate position value for each bright spot corresponding to each car, only moves by a limited number of pixels between NTSC frames. If, for example, the coordinate position value of a bright spot should suddenly appear a considerable number of pixels away from the previously calculated coordinate position value, the bright spot may be discarded as a solar reflection and not a bright spot generated by the optical identification signal. Appropriate processing algorithms may be incorporated into the image processing stages to increase the accuracy with which the desired bright spots are acquired.

The image processed optically filtered image frames which contain bright spots corresponding to each object (e.g. race car) are

received by a coordinate detector device **82**. The coordinate detector device **82** is a component of the picture frame processing system **68**. The coordinate detector device **82** determines the X (horizontal) and Y (vertical) coordinate position values of pixels saturated by bright spots generated by the optical identification signal emitted from each moving object (having an optical identifier device). For each moving object (e.g. race car) and during each 4ms subframe within an NTSC frame, the coordinate detector device **82** determines the bright spot X (horizontal) and Y (vertical) coordinate position value. Based on the movement of the determined coordinate position values corresponding to the object's movement, the coordinate detector device **82** carries out further processing steps to ensure smooth movement of the detected coordinate position values between successive NTSC image frames. The coordinate detector device **82** generates an X coordinate position signal, indicated at **84**, and a Y coordinate position signal, indicated at **86**, wherein the X coordinate position signal corresponds to a running average of the X coordinate position values determined from each subframe, and the Y coordinate position signal corresponds to a running average of the Y coordinate position values determined from each subframe. Each subframe essentially is an optically filtered image frame received from the second camera device **64** and each subframe is processed within an NTSC frame.

To determine the running average, a series of initially determined X and Y coordinate values are averaged over several subframes (e.g. over 15 subframes) and each new determined X and Y coordinate value is averaged with respect to the averaged X and Y coordinate values (e.g. over 15 subframes). Hence, the X coordinate position signal, indicated at **84**, and the Y coordinate position signal, indicated at **86**, generate current coordinate position values with smoothed movement with respect to the moving object. This coordinate averaging process between subframes also provides a coordinate position value prediction scheme for predicting the next coordinate position value of the object. This is particularly useful in instances during which the optical identification signal

cannot be processed during a subframe period.

The X and Y coordinate position signal is received by a picture-in-picture processor **88**. The NTSC picture-in-picture processor **88** generates an NTSC picture-in-picture signal, as indicated at **90.** The picture-in-picture processor **88** receives both an information graphic image, indicated at **92**, and NTSC broadcast image frames, indicated at **94**, from the broadcast camera **62** and generates the picture-in-picture signal, indicated at **90**. The picture-in-picture signal, indicated at **90**, is the superposition of the graphic image, indicated at **92**, and NTSC broadcast image frames, indicated at **94**. The picture-in-picture processor **88** superimposes the information graphic image onto the broadcast image frames at a location related to that indicated by the X coordinate position signal, indicated at **84**, and the Y coordinate position signal, indicated at **86**. As a result of the image capture system tracking the optical identification signal, the coordinate position value for each bright spot found in an optically filtered frame is always in the region of the optical identifier device **12**. Therefore, the generated X and Y coordinate position signals, indicated at **84** and **86**, will cause the graphic image to track the movement of the object for each NTSC frame. Furthermore, as the X and Y coordinate position signals, indicated at **84** and **86**, are based on averaged (running average) coordinate position values of each bright spot (within the optically filtered frames), the graphic image will smoothly track the image of the moving object during the NTSC image frames. An example of the graphic image **28** is shown in Figure 2.

The picture frame processing system **68** further includes a graphic insert generator **98** and an information data base **100**. The image tracking system allows a graphic image insert containing information to track the movement of the image of the moving object. This information is specific to each object being tracked. For example, if four race cars are being tracked, then each car will have a graphic image with information regarding the driver and his or her performance. The displayed NTSC picture-in-picture signal, indicated at **90**, will show a graphic image with

inserted information, wherein the graphic image tracks a corresponding race car image across the display screen (e.g. TV screen).

In order to determine what information must be inserted within an object's graphic image, a unique identifier decoder device **102** decodes the unique identifier code modulated onto the optical identification signal emitted from each moving object. As previously discussed, each moving object (up to a maximum of four in the example described) emits an optical identification signal modulated with its own unique identifier code. Within each subframe, the unique identifier code is extracted from each optically filtered image frame, wherein the unique identifier code identifies which object has emitted the optical identifier signal. The extracted unique identifier code is received by the information database **100**, which generates the statistics and necessary information related to the object having that unique identifier code. The statistics and necessary information generated by the database **100** are received by the graphic insert generator **98** and inserted within an information graphic image, which is received by the picture-in-picture processor **88**. The picture-in-picture processor **88** superimposes the graphic image onto the NTSC image frame at a coordinate position close to the corresponding object to which the information is related. It will be appreciated however, that generating an information thumb nail graphic image for each object occurs within that object's designated subframe period (~4ms), and that the corresponding coordinates of this object for inserting the graphic image are also generated within this subframe. This applies for other objects being tracked.

Figure 5 illustrates an alternative embodiment of the present invention, wherein the image capture system comprises a single lens imaging system. The operation of components **76A**, **78A**, **80A**, **82A**, **88A**, **98A**, **100A** and **102A** of the picture frame processing system **68A** is identical to that of components **76**, **78**, **80**, **82**, **88**, **98**, **100** and **102** respectively of the picture frame processing system **68** illustrated in Figure 4. The mechanical structure or arrangement of the first and second camera device **106**, **108**, is such that they share the same camera lens system **110**.

The camera lens **110** comprises an optical splitter **112**, which receives a first and second optical signal, wherein the first optical signal is the image of the moving object and the second optical signal is the optical identification signal emitted from this moving object all combined as a single optical signal.

The optical splitter **112** directs the image of the moving object along a first optical path and directs the optical identification signal along a second optical path, wherein the first and second optical paths are orthogonal. The image of the moving object directed along the first optical path is received by a first camera **106** and the optical identification signal directed along the second optical path is received by the second camera **108** and then is additionally optically filtered by a narrowband optical filter **114**. The difference between the two cameras is that one camera (first camera **106**) generates a first series of image frames which include broadcast quality image frames of the moving object (or objects), whilst the other camera (second camera **108**) generates a second series of image frames which include optically filtered image frames of the optical identification signal (or signals). The optically filtered image frames and broadcast quality image frames are processed within the picture frame processing system **68A** in an identical manner to that described previously in relation to the picture frame processing system **68** of the embodiment of Figure 4.

Figure 6 illustrates the optical system within the single lens imaging system of Figure 5. The optical system comprises the optical splitter **112** (a dichroic mirror), a first lens **116**, a second lens **118**, a first focusing lens **120** and a second focusing lens **122**. The image of the moving object (or objects) and the optical identification signal (or signals) emitted from each moving object (maximum of four), as indicated at **124**, are received by the first and second lens **116**, **118**. The separation of the first and second lens **116**, **118** is selected to be equivalent to the sum of each lens focal length. In this lens configuration the received image of the moving object (or objects) and the optical identification signal (or signals)

form a collimated beam which is incident on the dichroic beam splitter **112**. The dichroic beam splitter **112** transmits the incident collimated image of the moving object (or objects) along the first optical path to the first focusing lens **120**. The first focusing lens then focuses the collimated image of the moving object (or objects) onto the first camera **106**, wherein the first camera **106** generates image frames of the moving object at the NTSC rate (60 frame/sec).

On the other hand, the dichroic beam splitter **112** reflects the wavelength of the collimated optical identification signal along the second optical path through the narrowband optical filter **114** to the second focusing lens **122**. The second focusing lens **122** focuses the collimated optical identification signal onto the second camera **108**, wherein the second camera **108** is a high frame rate camera (four times NTSC rate) which generates the optically filtered image frames of the optical identification signal. The optically filtered image frames and image frames of the moving object are processed by the picture frame processing system as explained previously.

In accordance with the present invention, the moving object is tracked whether it is stationary or moving and during both panning and zooming functions of the camera or cameras. The object may be a race car or a police car being tracked with a camera from the air. The applications of the invention are extended to tracking any object or vehicle having an optical identifier device and the coordinate position value can be used to initiate automated tracking of the vehicle or object.

It will also be appreciated that the present invention relates to any imaging system requiring the tracking of an object image. The invention is applicable to other broadcast standards such as PAL, SECAM or any other broadcast or imaging standard that may emerge in the future.

It should be understood that various modifications can be made to the preferred and alternative embodiments described and illustrated herein, the scope of which is defined in the appended claims.